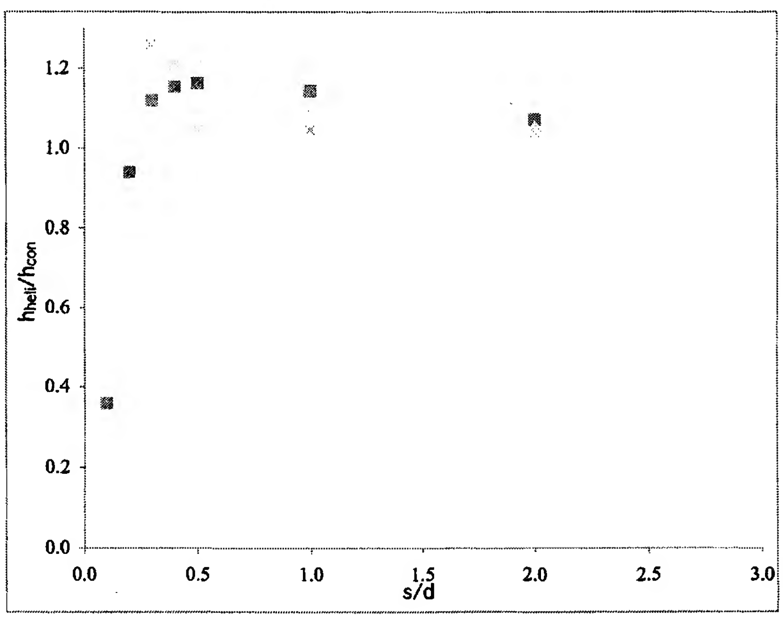
INVENTOR'S DECLARATION
UNDER § 1.132

The question is presented to me whether the structure of the Steenstrup device (U.S. Patent 1,736,635) anticipates the presently claimed invention. It cannot. Specifically, the present invention as claimed provides greater than unexpected results in comparison to the device described in Steenstrup and any other known heat exchanger.

The graph below is a plot of the ratio of heat transfer coefficient for the helicoidal heat exchanger to that of a conventional heat exchanger as a function of the tube spacing to tube diameter ratio. As can be seen, for the conditions of the experiment, there is an optimum spacing, when the gap between two adjacent tubes (tube spacing) is about 0.4 diameter of the pipe. At this optimum point, the heat transfer coefficient on the outside can be over 20% higher than that of conventional heat exchangers. Beyond this point, as the tube spacing increases, there is little change in the heat transfer coefficient, showing that the tube spacing can be substantially reduced.



Further, in a typical conventional heat exchanger used in window air conditioners, the tube diameter is about 3/8 inches and the tube spacing is about ¾ inches. Accordingly, in a typical heat exchanger with 11 rows, the height would be around 11*(3/8+3/4) = 12.4 inches. However, a helicoidal heat exchanger can be built having a tube spacing of approximately 0.4*3/8 = 0.15 inches for a total height of 5.8 inches. This is more than a 50% reduction in the height of the heat exchanger.

Also, it has been shown that the inside heat transfer coefficient is typically 20 to 40% higher due to the curvature of the tube. Therefore, the overall heat transfer coefficient which is given by

$$\frac{1}{h}=\frac{1}{h_{outside}}+\frac{1}{h_{inside}} \tag{1}$$

will also be 20% higher. Accordingly, the size of heat exchanger can be reduced by 20%, or one row could be eliminated, thereby making a substantial saving in size and material.

Additionally, the present invention has substantial advantages when it comes to pressure drop. A conventional heat exchanger having a total pipe length L is made up of N equal length (rows) each having a length L/N. Each tube segment is attached to the next by a U bend (hair pin). As such, a total of N-1 U bends are needed. The pressure drop for this combination is

$$\frac{\Delta P_{conv}}{\rho g}=f_{straight}\frac{L}{d}\frac{V^2}{2g}+(N-1)K\frac{V^2}{2g} \tag{2}$$

where K is the friction coefficient for the U bend. Calculating the ratio of the pressure drop in a conventional heat exchanger to that of a straight pipe becomes

$$\frac{\Delta P_{Conv}}{\Delta P_{straight}}=1+(N-1)\frac{K}{f}\frac{d}{L} \tag{3}$$

For a typical 18 inch long heat exchanger having 11 rows made of ½ inch pipe:

$$\frac{\Delta P_{Conv}}{\Delta P_{straight}} = 1 + (11 - 1)\frac{1.5}{.015}\frac{3/8}{18 * 11} = 2.89 \qquad (4)$$

However, for a helicoidal pipe of the same length the pressure drop is 20% to 30% higher than that in a straight pipe. Therefore comparing the above conventional heat exchanger to a helicoidal heat exchanger of the same length,

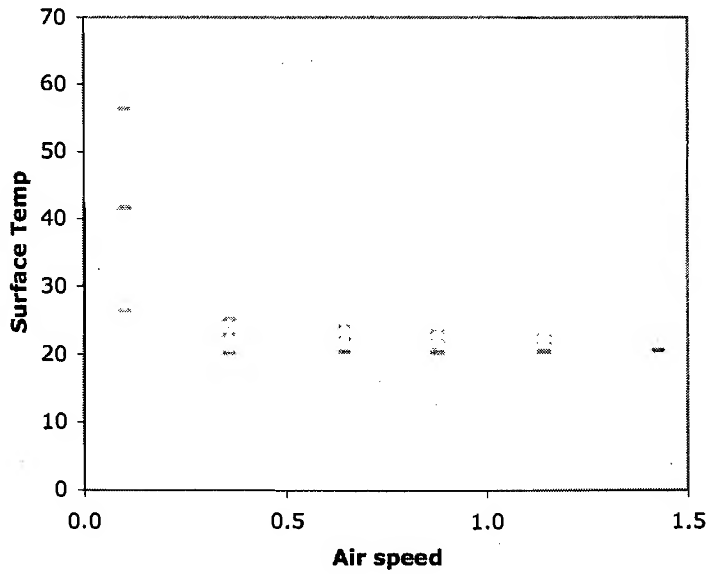
$$\frac{\Delta P_{heli}}{\Delta P_{Conv}} = \frac{1.3}{2.89} = 0.45 \qquad (5)$$

Accordingly, the pressure drop is less than half of a conventional heat exchanger. This may allow the use of a smaller diameter pipe which further reduces the overall size and material costs.

Furthermore, excluding the fin width, since a finned helicoidal heat exchanger is round, for the same length, it will be about 1/3 as wide as a rectangular heat exchanger of equal tube. For example an 18 inch long heat exchanger will be around 6 inches wide. This reduction in length is accompanied by a proportionate increase in the depth. Therefore an 18x11 inch heat exchanger can be shrunk into a 5x6 inch heat exchanger.

Additionally, the finned helicoidal heat exchangers allow the use of a sirocco fan (squirrel cage) blower in the center of the coil cavity. This is another important advantage of the invention; its ability to use a blower instead of a fan. This not only substantially reduces the overall size of the unit, since the blower is placed inside the coil cavity, it also provides for a far more uniform flow over the coil. The scroll cage blower provides more uniform cooling. In conventional heat exchangers, a round fan is placed in front of rectangular heat exchangers leading to a large variation on the flow speed over conventional heat exchangers. Below is a plot of our experimental measurements of the

average surface temperature of the heat exchanger as a function of air (blower) speed. As can be seen, for the experimens performed, the surface temperature drops substantially past the airflow rate of 0.4 m/s and stays constant after that. This means that the heat exchanger can overate with a much lower fan power.



Preliminary research work on measuring the heat transfer from the outside of the heat exchangers indicates that there may also be improvements due to the more uniform air flow. Also, due to the tubes curvature and wedge shape of the fins the outside heat transfer rate is also higher.

The only published research on the performance of finned helical-coil heat exchangers is a single paper published in 2007 by Paisarn Naphon titled "Thermal performance and pressure drop of the helical-coil heat exchangers with and without helically crimped fins". This paper confirms the advantages of this patent application. The existence of only one research article is further evidence of its novelty and lack of obviousness.

Using finned helicoidal heat exchangers in vapor compression refrigeration and air condition cycles has the potential for significant contributions in improving the efficiency of the cycles compared to those using traditional heat exchangers. A reduction in the overall use of electricity for air conditioning is expected to occur by the inventions' enabling capabilities. The dramatically reduced foot-print of the proposed design allows the incorporation of other energy saving options.

These advantages of the present invention are not obvious, not only because no such product is on the market, but because some of the advantages are surprising. An air conditioner using this heat exchanger design is completely practical and has numerous advantages over the conventional ones.

These advantages not only lead to improvements in conventional air conditioning systems and how they are utilized, but may be proven suitable for use in air conditioning systems that utilize alternative refrigerants like carbon dioxide and operate at elevated pressures, as well as automobile air conditioners since it has the potential to cut the size of an automobile air conditioner in half or more. Additionally the heat exchangers can be used in applications requiring high temperature and/or pressure such as fuel cells, next generation nuclear power plants, and so forth.

Given the unexpected results shown by the presently claimed invention, the prior art of record cannot disclose the invention as described. Rather, the unexpected differences in the properties of the claimed invention and the prior art render the claimed invention patentable over the cited art. Specifically, it is evident that if the present invention were not novel as suggested by the Examiner, the technology described in the present application would clearly be in everyday use today. The lack of technology

similar to the present invention, in light of the present invention's superiority over known technology, clearly indicates that the present invention is novel over the cited art.

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